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AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION

Applicant(s):

MITCHELL JOE DODSON

Invention Title:

NOZZLES

The invention is described in the following statement:

TITLE

NOZZLES

FIELD OF THE INVENTION

This invention relates to nozzles and more particularly to flat jet nozzles especially, but not exclusively, for use in snowmaking equipment. The invention also relates to snowmaking equipment.

BACKGROUND OF THE INVENTION

There are many types, designs and configurations of nozzles that are particularly used in industrial situations for the spraying of fluids. Nozzles of this kind are used in the irrigation, cleaning, painting and fire extinguishing industries. Spraying systems incorporating nozzles of this kind have wide ranging industrial applications. Nozzles are also used in snowmaking equipment and the nozzle that is the subject of this invention has its primary use in snowmaking equipment.

Flat jet nozzles that produce a flat spray pattern are known. They distribute liquid as a flat or sheet type spray. Some use elliptical orifices with the axis of the spray pattern being a continuation of the axis of the inlet pipe connection. Others use a deflector, the deflecting surface diverting the spray pattern away from the axis of the inlet pipe connection. There are a number of different nozzles that provide a flat spray pattern. Variations of these nozzles provide considerable variations in the spray pattern. The adjustability of nozzles of this kind is usually confined to variation in the liquid pressure.

There are a number of parameters that contribute to successful snowmaking. The constant fluctuations in these parameters means that efficient snowmaking equipment needs to be continually adjustable to ensure optimum efficiency. The adjustability and resultant efficiency is critical to successful snowmaking and often critical to the economics of a ski resort.

It is the issues surrounding the design of nozzles that produce a flat spray pattern and the issues of snowmaking equipment that have brought about the present invention and its derivatives.

SUMMARY OF THE INVENTION

In accordance with one aspect of the present invention there is provided a nozzle for producing a flat spray pattern, the nozzle comprising a fluid passageway terminating in an end wall having an outlet aperture, the fluid passageway having at least one deflector that deflects the fluid towards the aperture; and adjustable means to vary the cross section of the aperture. Preferably, the fluid passageway has at least two wall portions that converge towards the aperture. The means to vary the cross section of the aperture may comprise displaceable shutters that move from opposite sides of the aperture to close off or increase the aperture of the cross section.

Preferably, the end wall is furnished by a cross tube that extends across the end of the fluid passageway, the tube supporting axially displaceable pins that close off or open the aperture.

In a preferred embodiment means is provided to control the displacement of the pins in and out of the cross section of the aperture.

In a preferred embodiment the nozzle comprises a T-piece, the leg of which is a circular pipe defining a fluid passageway and the head of the T being a pipe of circular cross section across the end of the fluid passageway, an aperture is positioned in the head of the T-piece axially aligned with the fluid passageway, a cylindrical pin terminating in a planar face is positioned at each end of the head of the T-piece to be displaceable along the T-piece so that the ends of the pin can move across the aperture to vary the cross section of the aperture.

In the preferred embodiment the diameter of the fluid passageway is the same as the diameter of the aperture. It is also preferable that in adjusting the cross section of the aperture the pins move the same distance in opposing directions.

According to a further aspect of the present invention there is provided snowmaking equipment comprising at least one flat jet water nozzle inclined upwardly to, in use, project a plume of water droplets, the nozzle being positioned adjacent a jet of compressed air, the nozzle having an outlet aperture, and means to vary the cross section of the aperture to adjust the characteristics of the plume to suit the ambient conditions.

Preferably, the jet of compressed air is placed downstream of the nozzle. The jet of compressed air preferably comprises an array of apertures. The width of which equates to the width of the plume at the air jet.

Preferably, the four flat jet water nozzles are positioned spaced apart in a horizontal plane, the spacing of the nozzles equating to the maximum width of each

plume.

In accordance with a still further aspect of the present invention there is provided snowmaking equipment comprising a rotatable mast that supports a head, the head comprising at least two spaced apart flat jet water nozzles, each nozzle having an outlet aperture, each nozzle being positioned adjacent a jet of compressed air and means to vary the cross section of each aperture to vary the output of each nozzle.

Preferably, the head is vertically adjustable whilst maintain the angle of inclination of water and air nozzles. In a preferred embodiment, the plume of water droplets escaping from each nozzle is directed tangentially against the underside of the air jet. The air jet preferably has an array of a plurality of spaced outlet apertures, the width of the array being substantially the same as the width of the plume at the air jet.

Preferably, the head includes four nozzles spaced so that the plumes meet at their widest points.

DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described by way of example only in which:

Figure 1 is a perspective view of snowmaking equipment,

Figure 2 is a side elevational view of the snowmaking equipment in three different vertical positions,

Figure 3 is a plan view of the snowmaking equipment,

Figure 4 is a side elevational view of the snowmaking equipment when supported on an uneven inclined

surface,

Figure 5 is a detailed perspective view of the head of the snowmaking equipment shown in Figure 1,

Figures 6a, 6b and 6c are cross sectional views taken along the lines 6-6 of Figure 5 showing a water jet and air nozzle in three different relative positions,

Figure 7 is an enlarged cross sectional view of part of the head enclosed by the circle 7 in Figure 5,

Figure 7a is a cross sectional view of two adjacent nozzles illustrating a means of adjusting the nozzles,

Figures 8a and 8b are cross sectional views taken along the lines 8-8 of Figure 7 showing the outlet of the water jet in two positions,

Figure 9 is a cross sectional view taken along the lines x and showing the physical association of a water jet with an air jet,

Figure 10 is a cross sectional view illustrating the association of a plume of water contacting the air jet, and

Figure 11 is a perspective underside view of the air jet.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments that are illustrated in the accompanying drawings relate to snowmaking equipment that incorporates an adjustable flat jet nozzle. The invention covers both the nozzle per se applicable to many spraying industries as well as snowmaking equipment that incorporates a nozzle, it is however understood that the snowmaking equipment has many other features that contribute to its improved design and operation.

The nozzle 10 is shown in detail in Figures 7 and 8. Although it is shown in association with snowmaking equipment it is understood that this nozzle is applicable

to many fields totally unrelated to snowmaking. The nozzle has applicability in any industrial spraying application where there is a need for a variable flat jet nozzle.

As shown in Figures 7 to 9 of the accompanying drawings, an adjustable nozzle 10 comprises a T-piece 11, the leg 12 of which is a cylindrical fluid passageway that is secured to a rectangular mounting plate 13. Welded across the end of the leg 12 is a piece of cylindrical pipe 15 with a circular outlet aperture 20 positioned co-axially with the axis of the fluid passageway. The pipe 15 is hollow to accommodate a pair of cylindrical pins 21, 22. Each pin is cylindrical and terminates in a planar face 23 at one end. An O-ring 24 is located in a groove 25 on the exterior of the pin spaced from but close to the face 23. The other end of the pin is provided with an external thread 26 that is arranged to be a screw fit within a threaded sleeve 30 which is in turn welded to a radial flange 31 that joins a larger hollow sleeve 32 that operates as a pin guide. The circular cross section of the T-piece head 15 provides two converging surfaces that cause water flowing towards the aperture 20 to converge towards the aperture. The planar ends 23 of the pins 21, 22 operate to vary the cross section of the aperture 20. As the pins move in the pipe the ends progressively close off the aperture 20 as shown in Figures 8a and 8b.

The nozzle described above provides a flat spray profile. The exact profile varies in dependence with the position of the pins 21, 22 in the aperture 20.

Displacement of the pin guides 32 causes displacement of the pins 21, 22 to vary the cross section of the aperture 20. If the pin guides are coupled to a suitable servo mechanism the nozzle can have a constantly variable output depending on the position of the pins.

Ideally, each pin moves by the same amount in opposite directions.

The nozzle has the advantage that its output can be varied whilst maintaining full input fluid pressure. This differs from most flat jet nozzles where the adjustability is either by variation of the input fluid pressure or by changing the nozzle aperture by replacing the end of the nozzle.

Although in the preferred embodiment the outlet aperture 20 of the nozzle is circular, it is understood that other shapes are envisaged. A larger diameter aperture provides a small spray angle whilst a smaller aperture diameter increases the spray angle. A wide slot on the other hand provides a very wide spray angle. The fluid flow can be increased by increasing the width of the aperture 20 by moving the pins apart 21, 22. Conversely, a decrease in fluid flow is achieved by moving the pins 21, 22 together. Preferably, the pressure always remains constant, namely at its maximum. Use at maximum pressure results in higher velocity and smaller spray particle size. The closer the pins are together results in small spray particles and less fluid flow which is ideal for snowmaking.

Although the variable flat nozzle 10 described above is specifically designed for use with snowmaking equipment, it is understood that this nozzle could be used in a wide range of other industrial applications. The adjustability of the nozzle could be manual through use of a spanner, Allen key or similar such tool to displace the pins or through more automated means by driving the pin guides as shown in Figure 7.

Figures 1 to 11 illustrate snowmaking equipment S utilising a bank of four nozzles 10 of the kind described

above. As shown in Figure 3, the nozzles 10 are mounted spaced apart so that the plumes of water particles that are ejected from the nozzles meet at their maximum width.

As shown in Figure 5, the snowmaking equipment S comprises a mast M that is pivotally rotated about an adjustable base structure B that comprises three legs 51, 52, 53 mounted on adjustable skids 55 that extend outwardly by about 2 metres and are equally spaced around a common pitch circle. The legs 51, 52, 53 support an adjustable triangular bracing structure 60 on which the mast M is rotatably mounted. The mast comprises a vertical column 61 that is mounted centrally of the base structure B, the vertical column 61 has a rearwardly trailing arm 62 that terminates in a mounting bracket 63 that in turn pivotally supports two closely spaced parallelogram linkages 64, 65. The parallelogram linkages 64, 65 pivotally supports a head assembly H that is in the form of a pair of triangular support frames 66, 67 that are rigidly secured to the spray head H.

The spray head H is shown in Figure 5 and essentially comprises an elongate water pipe 71 referred to as a manifold that has projecting therefrom four adjustable nozzle assemblies 10 of the kind described above and shown in Figures 7 to 9. Each nozzle 10 is also associated with a compressed air jet 75 as shown in Figure 5. The jets 75 are interconnected by pipe 76 and fed by a common source of compressed air. The array of nozzles 10 and air jets 75 support a rectangular wind vane 74 shown in Figures 1 and 3. The compressed air and water are supplied to the head H by flexible pipes that run down the mast M to the ground as shown in Figure 4.

The parallelogram linkages 64, 65 are in a parallel closely spaced configuration. Each parallelogram linkages 64, 65 as shown in Figure 4 comprises two

elongate arms 68, 69 that are pivoted at one end to the mounting bracket 63 on the mast M and the triangular frame 66 or 67 on the spray head H at the other end. The parallelogram linkage has the opportunity of assuming a variety of vertical positions as shown in Figure 2. At the highest position the arms 68, 69 extend vertically whilst at a lowest position the arms 68, 69 are slightly extended below the horizontal. In each case the triangular support for the jet assemblies remains at the same angle to the horizontal. The triangular frames 66, 67 can be covered in sheet material to act as a subsidiary wind vane to the primary vane 74. The parallelogram linkages are attached to trailing arm 80 that is coupled to a spring 81 that is in turn attached to rearwardly extending flange 82 on the base of the mast M. The spring 81 acts to urge the parallelogram linkages 64, 65 to assume the vertical position and the lower positions are caused by wind impinging on the vane 74 to deflect the assembly down against the spring. It is understood that the spring could be adjustable and it is further understood that other mechanisms such as pneumatic or hydraulic dampers could replace the spring. The maximum height of the assembly S is approximately 6 metres.

As mentioned above, the spray head H incorporates four adjustable flat nozzles, each associated with a compresses air jet. The association of each adjustable flat nozzle 10 with the compressed air is illustrated in Figures 9 to 11. The air jet 75 is in the form of a tapered jet body 76 of triangular cross section that is inclined downwardly from the horizontal by 21°. The jet body 75 terminates in a plurality, preferably between three and fourteen small apertures 77. The underside of each aperture 77 has a trailing scalloped groove 78 that is cut out of the underside of the air jet and the arrangement of the water jets 10 is such that, as shown in Figure 10, the water first hits the underside of the air

jet 75 as it tangentially passes the ends of the air jets and the apertures 77. The holes 77 in the end 79 of the tapered nozzle body are drilled so that they extend to the bottom surface to merge with the trailing scalloped grooves 78. The thin edge that is defined at the top of the apertures reduces the surface area for ice to adhere. Furthermore, the velocity of the water plume P, as it passes the apertures, clears the ice away.

Figures 6a to 6c illustrates the adjustability of the air nozzle 75 and water jets 10. The air tube 76 is mounted on a elongate shaft 101 that is axially displaceable about a sleeve 102 that is held to a support bracket via a screw 103. The jets 75 are in turn mounted to the shaft to be rotatable about a substantially horizontally axis as shown in Figures 6a and 6c. The jets 75 can also be inclined relative to the air tube 76 through a flange bracket assembly 105 shown in Figure 6c. The position of the water jets and water supply arm are substantially fixed to the support bracket as shown in Figures 6a, 6b and 6c.

In order to explain the operation of the snowmaking equipment described above and, in particular, the sophistications and important characteristics that result in an improved snowmaking technique, it is first necessary to consider, in general terms, the science of snowmaking.

SNOWMAKING

Snowmaking is a heat exchange process. Heat is removed from snowmaking water by evaporative and convective cooling and released into the surrounding environment. This heat creates a micro-climate inside the snowmaking plume that is very different from ambient conditions. There are many variables that affect

snowmaking. Three of the most important variables are wet bulb temperature, nucleation temperature and droplet size. Wet bulb temperature, the temperature of a water droplet exiting a snow gun is typically between +1°C and +6.5°C. Once a water droplet passes a nozzle and is released into the air, its temperature falls rapidly due to expansive and convective cooling and evaporative effects. The droplet's temperature will continue to fall until equilibrium is reached.

This is the wet bulb temperature and it is as important as dry bulb (ambient) temperature in predicting snowmaking success. For example, snowmaking temperatures at -2°C and 10% humidity are equivalent to those at -7°C and 90% humidity.

Once the wet bulb temperature is known, there must be a way to predict whether water droplets will actually freeze at that temperature. Ice is the result of a liquid (water) becoming a solid (ice) by an event called nucleation. In order to freeze, a water droplet must first reach its nucleation temperature. There are two types of nucleation, homogeneous nucleation and heterogeneous nucleation.

Homogeneous nucleation occurs in pure water in which there is no contact with any other foreign substance or surface. With homogeneous nucleation, the conversion of the liquid state to solid state is done by either lowering temperatures or by changes in pressure. However, temperature is the primary influence on the conversion of water to ice or ice to water. In homogeneous nucleation, the nucleation begins when a very small volume of water molecules reaches the solid state. This small volume of molecules is called the embryo and becomes the basis for further growth until all of the water is converted. The growth process is controlled by the rate of removal of the

latent heat being released. Molecules are attaching and detaching from the embryo at roughly equal and very rapid rates. As more molecules attach to the embryo, energy is released causing the temperature of the attached molecules to be lower than the temperature of the unattached molecules. The growth rate continues until all the molecules are attached. At this point, the solid state (ice) is established. Many people think that pure water freezes at 0°C or 32°F. In fact, the nucleation event (freezing) for pure water will take place as low as minus 40°C or minus 40°F. This is most likely to occur in laboratory experiments or high in the upper atmosphere (upper troposphere).

Heterogeneous nucleation occurs when ice forms at temperatures above minus 40°C or minus 40°F due to the presence of a foreign material in the water. This foreign material acts as the embryo and grows more rapidly than embryos of pure water. The location at which an ice embryo is formed is called the ice-nucleating site. As with homogeneous nucleation, heterogeneous nucleation is governed by two major factors: the free energy change involved in forming the embryo and the dynamics of fluctuating embryo growth. In heterogeneous nucleation, the configuration of molecules and energy of interaction at the nucleating site become the dominating influence in the conversion of water to ice. Snowmaking involves the process of heterogeneous nucleation. There are many materials and substances which act as nucleators; each one promotes freezing at a specific temperature or nucleation temperature. These nucleators are generally categorised as a high-temperature (i.e. silver iodide, dry ice, ice and nucleating proteins) or low-temperature (i.e. calcium, magnesium, dust and silt) nucleators. It is low-temperature nucleators that are found in large numbers in untreated snowmaking water. The nucleation temperature of snowmaking water is between -10°C and -7°C.

Why are warnings of freezing at temperatures around 32°F? The answer is that the "near factor" is coming into play with the freezing process. That factor is called surface (i.e. roads, highways, trees). There is an energy interaction between the ice- nucleating sites in the water with the surface. This causes the water droplets to freeze very near 32°F or 0°C. In snowmaking it is the nucleator having the highest nucleation temperature that determines when a water droplet will freeze.

Research has demonstrated that 95% of natural, untreated water droplets will freeze at widely different temperatures, the average temperature being 18.2°F. Introducing a consistent high temperature nucleator into the water will raise the freezing point. As a water droplet cools, heat energy is released into the atmosphere at a rate of one calorie per gram of water. As it freezes into an ice crystal, the water droplet will release additional energy at a rate of 80 calories per gram of water. This quick release of energy raises the water droplet temperature to 32° F, where it will remain while freezing continues. This is one reason why we are accustomed to thinking that water freezes at 32°F or 0°C. The water will continue to freeze as long as it remains at or below 32°F or 0°C, but only after it has first cooled to its nucleation temperature. Any excess energy will be dissipated into the atmosphere. Since the distribution of various nucleators in a given volume of water is totally random, the size of the water droplet or the number of high-temperature nucleators has a significant effect on the temperature at which freezing occurs (nucleation temperature). In natural water, as the size of the water droplet decreases, the likelihood that the droplet will contain a high-temperature nucleator also decreases. Conversely, larger water droplets stand a better chance of containing high-temperature nucleators. The optimum

situation for snowmakers is one in which every droplet of water passing through the snow gun nozzle contains at least one high-temperature nucleators and freezes in the plume.

The relationship between the variables of nucleation temperature and droplet size is summarised in two statistically valid conclusions. First, a 50% increase in the droplet size results in a one-degree, F increase in nucleation temperature. Second, a 50% decrease in droplet size results in a three-degree, F decrease in nucleation temperature. These conclusions are based on an average droplet size of 300 microns, and indicate that decreasing the droplet size can be counter-productive to promoting high-temperature nucleation, unless enough high-temperature nucleators are present. Looking at the relationship between droplet size and evaporation, research in cloud seeding shows that:*A 50% decrease in droplet size produces, a four-fold increase in the evaporation rate. *A droplet that is 50% smaller will evaporate to nothing after falling just one-eighth the distance that the average 300 micron droplet falls. These conclusions further point out the undesirable results from using very small droplets, especially in areas where water loss is a critical issue. Relating droplets size to nucleation temperature, it is possible to increase snowmaking production and efficiency by using high-temperature nucleators with larger water droplets. This method frequently allows for increased water flow, reduces evaporation, and yields more snow on the ground. In fact, studies indicate that a 20% increase in water flow can increase snow volume up to 40% if droplet size and nucleation temperature are optimised.

Summary

The snowmaking process involves spraying water

droplets into the cold ambient air, heat from the water droplets is transferred into the ambient air and the water droplets begin to freeze. If there is sufficient temperature differential between the water droplets and sufficient hang time the water droplet will freeze before hitting the ground. The volume of water that can be converted into snow depends on many factors.

<u>Initial Water Temperature</u> - a higher temperature of the water means that more heat needs to be removed before freezing can occur. Before water can freeze it must achieve a minimum temperature of 0°C.

<u>High-Temperature Nucleators</u> - Once a water droplet achieves a temperature of 0°C it needs a high temperature nucleator to be present before the water droplet will give off its latent heat and convert to snow. Water can be super cooled to -40°C without high temperature nucleators and not freeze.

<u>Droplet Size</u> - The size of the water droplet determines its ability to convert to snow. There are many methods to convert a water stream into water droplets of varying sizes, use of water nozzles and compressed air are two of the predominant methods. Small water droplets offer more surface area to the ambient air but are prone to evaporation in low humidity and are less likely to have high temperature nucleators present. Being smaller they have less mass and are vulnerable to high winds which can carry them away - smaller particles also have a lower velocity and a greater hang time. Small water droplets are desirable at marginal snowmaking temperatures due to the larger surface area and a greater hang time which aids when there is a low temperature differential with the ambient air. The larger surface area also assists the evaporative cooling effect.

Larger water droplets have less surface area, greater mass, higher velocity and have a higher chance of having high temperature nucleators present. When the ambient air is colder the temperature differential is greater with the particle temperature therefore a greater heat exchange occurs. The latent heat that is given off by the water particles is easily dissipated into the surrounding ambient air. The higher the velocity the greater the heat exchange.

A snowmaking gun should therefore produce a small droplet size in marginal conditions and a larger particle in colder conditions.

Hang Time - The longer the water droplet is in contact with the ambient air the more chance the particle has to freeze. A snowmaking gun has a greater production the higher it is in the air. Droplets projected at a higher velocity will also achieve a greater hang. It is imperative to get a snowmaking gun as high as possible and project the particles as fast as possible.

Water Volume - Given the above factors there is only a certain volume of water that can be converted in snow depending on the efficiencies of the above factors. Control of the water volume needs to be incorporated into any snowgun design to compensate for the change in ambient temperatures.

High Temperature Nucleation - Most snowmaking guns have a system that produces high temperature nucleators mostly in the form of ice crystals. This is usually achieved by combining water and compressed air.

Compressed Air - Air is a gas - or more accurately, a mix of gases. Unlike liquids, gases are compressible; a given volume of air can be contained in a

much smaller space. In order to fill that smaller space, however, the gas will exist at a higher pressure. A basic law of physics indicates that the pressure of a gas and its volume are related to its temperature; when pressure goes up, so does the temperature. But the temperature doesn't necessarily stay high - it can be decreased.

When a compressed gas is released and goes back to its original pressure, a great deal of mechanical energy is released. At the same time, a great deal of heat is absorbed. It is these last two characteristics that make compressed air such important factor in snowmaking. The mechanical energy released by the air disrupts the stream of water in tiny droplets, and then propels them into the atmosphere. As compressed air escapes the gun, it absorbs heat - in other words, cools.

Current Art of Snowmaking

Currently there are four different methods of snowmaking:

1. Fan Guns
2. Internal mix Air water guns
3. External mix - Air water guns
4. Water only guns

Fan Guns consist of a large barrel with an enclosed electric fan that forces large volumes of ambient air through the barrel. On the end of the barrel there is a configuration of water nozzles usually arranged in banks that can be turned on independently of each other. Each bank can consist of up to 90 small capacity hollow cone nozzles which produce very fine particles. The water particles are projected into the ambient air by the large volume of air that the fan produces. Fan Guns usually have an outer ring that is called the nucleating ring. This ring has a small number of miniature air/water nozzles

that operate in the same way as an internal mix air/water gun. An onboard compressor is used to operate this ring. The nucleating ring's primary role is to produce ice crystals. The ice crystals are carried along the outside of the bulk water plume for a distance before becoming ingested into the plume thus nucleating the bulk water plume. Operation of the fan gun is achieved by opening one bank of nozzles at a time and altering the water pressure to the nozzles. Once full pressure is achieved on a bank another bank is opened and the water pressure is adjusted.

<u>Internal Mix Air/Water Guns</u> - consist of a compressed air line and a water line converging into a common chamber with an exit orifice. Compressed air enters the common chamber and expands breaking up the water stream into smaller particles and projecting them into the ambient air. Operation of the gun is achieved by regulating the water pressure entering the common chamber. A common feature of the internal mix gun is that when water flow is increased air flow is decreased and visa versa. Water pressure cannot usually exceed the air pressure which is usually 80 - 125psi. There are a multitude of orifice and mixing chamber shapes that produce a wide variety of plumes and droplet sizes.

<u>External Mix Air/Water Guns</u> - usually consist of a configuration of fixed orifice flat jet nozzles arranged on a head that spray water into the ambient air. The head is usually put on a mast in order to give the water droplets more hang time due to the fact there is no compressed air to break the water droplets into smaller particles or to propel them. As with the fan guns the external mix guns have nucleating nozzles that use small internal mix nozzles to produce ice crystals which are directed into the bulk water plume. Control of the gun is by changing the fixed orifice flat jet nozzles for a different size or opening banks of nozzles as with the fan

gun.

Water Only Guns - Water only snow guns have no compressed air or nucleating nozzles. The head comprises a number of flat jet nozzles assembled on a high mast, usually a minimum of 6 metres in height. Snowguns of this type can only be used at temperatures starting at -6°C and work better with a high temperature nucleation additive.

THE PREFERRED EMBODIMENT

The snowmaking equipment that is the subject of this application differs from the existing technology by the fact that it uses the maximum efficiencies of each component involved in the process. The snowmaking equipment S is an external mix air/water gun utilising a bank of four variable nozzles 10 that provide a flat output pattern for the water to configure on a flat horizontal plan. Compressed air is introduced into the water plume P in a flat configuration and has the same dimensions as the water plume at the point of intersection. A significant feature of this snowmaking equipment is that control of the gun is by adjusting the nozzle orifice size and thus changing the water flow. This allows the maximum pressure of the water to be utilised creating a consistent droplet size with a higher velocity and throw than the conventional snowmaking guns.

The adjustment of the nozzle orifice size is carried out by displacement of the pins 21, 22. As shown in Figures 7 and 8. To displace the pins to vary the cross section of the outlet aperture 20 of each nozzle 10, the pin support sleeves 30 are connected to slides 32 via webs 39. The slides are positioned co-axial of the air pipe 76 and, as shown in Figure 7a, each sleeve 32 is arranged to be a sliding fit on the air pipe 76. All the left hand sleeves 30 of the adjustable nozzles 10 are

connected to a first elongate rod 90 and all the right hand sleeves 30 are connected to a second elongate rod 91. The rods 90 and 91 are bolted to the respective sleeves 32 so that displacement of the rods 90, 91 has the effect of moving the sleeves 32 to in turn move the pins 21 or 22 in and out of the aperture 20 of each nozzle 10. The rods 90 and 91 are coupled to threaded bosses 97, 98 that support externally threaded rods 92, 93 that extend from opposite sides of a bevel gear 94. The bevel gear 94 meshes with a second bevel gear 95 connected to a shaft 96 that extends down the mast so that it can be driven from the base of the mast. Thus, rotation of the shaft 96 imparts rotation to the two rods 92, 93 extending from the beveled gear 94. The two shafts 92, 93 have opposite threads so that the left hand shaft has a left hand thread that has the effect of moving the boss 97 to displace the first rod 90 in one direction and the right hand shaft 93 has a right hand thread to move the boss 98 to displace the rod 91 in the opposite direction.

As shown in Figures 8a and 8b, fine tuning of the position of the pins 21, 22 can be done by adjusting the threaded end 26 of the pins in their sleeve by use of an Allen key.

The compressed air is introduced into the water plume P directly at the point where the compressed air has the most energy. The maximum energy from the compressed air greatly increases the atomization of the water particles, and gives the maximum cooling and projection of the water droplets. The temperature directly at the exit of the air orifices can be as low as -40°C which drops the bulk water plume to around 0°C and lower, the extreme cold air also creates ice crystals, some which are carried in the bulk water plume while some are blown out of the plume and are re-ingested at a further distance. This high concentration of ice crystals ensures that there is an

abundance of high temperature nucleators to seed the majority of the water droplets.

If ice crystals are injected into the bulk water plume before the plume temperature is 0°C the ice crystals will melt, this is why other external mix guns project the ice crystals that are produced into the plume at a further distance away from the water nozzle so that the bulk water has had enough time for the heat in the water to be carried away by the ambient air before they are introduced. In windy conditions some of these ice crystals can be carried away reducing the nucleation of the bulk water.

Internal mix guns utilise the compressed air in the same way with the exception that the energy of the water pressure is not utilised as it is regulated to control the water flow. The maximum water pressure for most internal mix guns usually does not exceed the compressed air pressure (that is 7 bar - whereas the variable flat jet can operate at pressures exceeding 40 bar). The nature of a fixed chamber dictates that the more water is used the less air that can be in the chamber by volume and the same in reverse. The compressed air is the only means for projection and atomisation of the water; when the amount of compressed air is limited by a greater water flow efficiencies are decreased. Because the energy of the water is not utilised there has to be an increase in the volume of compressed air that is used making the gun more expensive and noisy to run.

The snowmaking equipment of the preferred embodiment uses the same amount of compressed air no matter what the water flow giving a more linear curve and allowing greater production per gun and because it has lower consumption of compressed air applied directly into the plume using smaller air orifice size resulting in

considerably quieter operation. The synergy of these two mediums gives the most efficiency that can be obtained creating a consistent plume of homogenous medium sized water particles that have the highest possible velocity and high temperature nucleators (ice crystals) possible.

Because external mix guns do not use compressed air to atomise the water plume the droplets that are formed are much larger with a greater range of differing sizes within the plume. At lower pressures the droplets can be as large as 1000 to 4000 microns where as the preferred embodiment produces droplets in the 300 to 600 micron range.

The preferred embodiment has a very high plume velocity and surface area which causes more ambient air to be inducted into the plum giving added cooling. The shape of the wind vane 74 on the head H resembles a tilted airplane wing and directs the wind from behind the head to accelerate over the nozzle outlet increasing the amount of cold air into the plume and helping to accelerate its velocity.

The preferred embodiment utilises a portable mast arrangement that allows the head to be positioned 1 metre to 6 metres above the ground. The main mast members form a parallelogram to which the head is attached to the top, when the mast is lowered and raised the head maintains a constant angle giving a consistency in the trajectory of the plume. Other snowgun masts have a fixed mast so that when the mast is lowered the angle of the head points progressively more into the ground decreasing the snowguns efficiency. Most external mix guns cannot be lowered as they rely on the height of the mast to produce sufficient hang time for the water droplets to freeze. The apparatus of the preferred embodiment can produce snow efficiently 1 metre above the ground - the efficiency increases with

height.

Most 6 metre masts for snowguns are in permanently fixed ground positions. The apparatus of the preferred embodiment can be towed by a snowmobile and set up at different locations. The legs of the mast has skids attached so that it can be easily towed; the legs are also adjustable so that the mast can be levelled on uneven terrain, see Figure 4. The flat profile of the legs reduces the hazard to skiers. The main mast swivels at the base which allows the head to be turned with the wind. The wind vane 74 on the head H catches the wind and pushes the head downwind in the same way a weather vane works. This increases the gun's efficiency as cross winds affect the efficiency of the plume by blowing the bulk water together lessening the surface area and velocity. The mast is counterbalanced by a spring 81 which a quick, easy raising and lowering of the mast. The wind vane 74 is tilted upward and in the event of high winds this automatically lowers the height by pushing the head closer to the ground. This aids in more snow being deposited on the ski run; if the mast were to remain at its maximum height in high winds the snow produced would be more likely to be carried away.

In the event of heavy ice conditions the head lowers itself under the weight of the ice so that it can be easily de-iced by staff.

The apparatus of the preferred embodiment has the same efficiency and production as a fan gun but produces larger water particles. Fan guns are more expensive to purchase and need more electrical infrastructure on the mountain therefore limiting their movement. Movement of fan guns require the use of expensive snow grooming machines because of their size and weight. Expensive permanent tower designs are necessary to raise a fan gun 6

metres into the air which introduces additional risks to the staff as the fan guns require staff to perform duties at height e.g. taking off covers, de-icing of controls.

In a more sophisticated version of the equipment, a wet bulb temperature sensor is incorporated with an ambient temperature sensor that also sensors the temperature of the water. A water pressure sensor is also included. A computer constantly monitors the readings of the sensors and selectors a nozzle aperture size that it is optimum to produce snow most efficiently in the set conditions. The use of electrically powered servo motors thus allows continual adjustment of the nozzle apertures in dependence on changes in the ambient conditions. Changes in direction and strength of the wind is accommodated by the vane on the head of the mast that causes the mast point down wind and the head to assume the appropriate height as directed by the wind. The parallel linkage ensures that the nozzles are inclined at the right angle to the horizontal regardless of the effective height of the mast.

Dated this 1st day of April 2003

MITCHELL JOE DODSON

By their Patent Attorneys

GRIFFITH HACK

Fellows Institute of Patent and

Trade Mark Attorneys of Australia

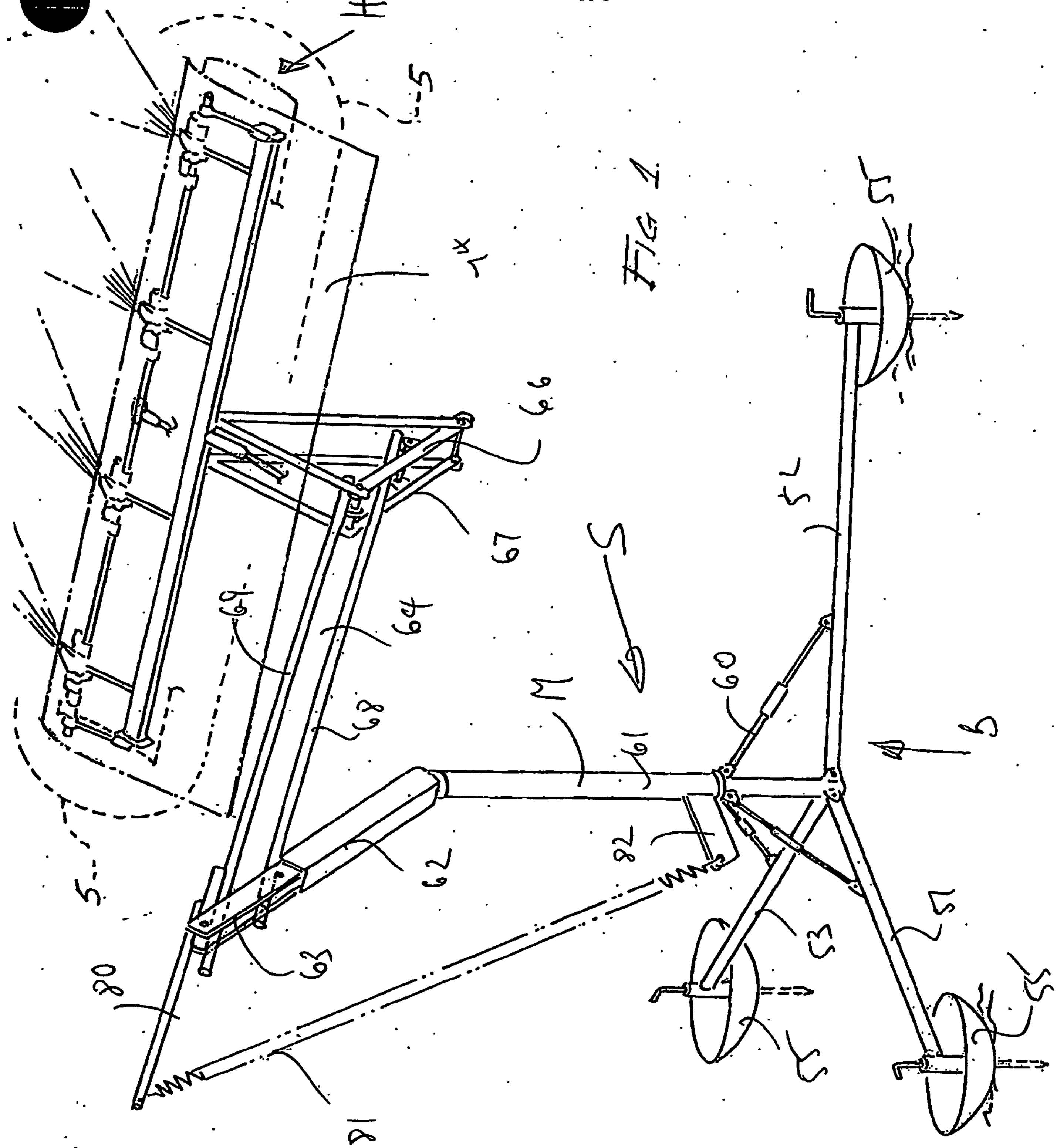

FIG 1

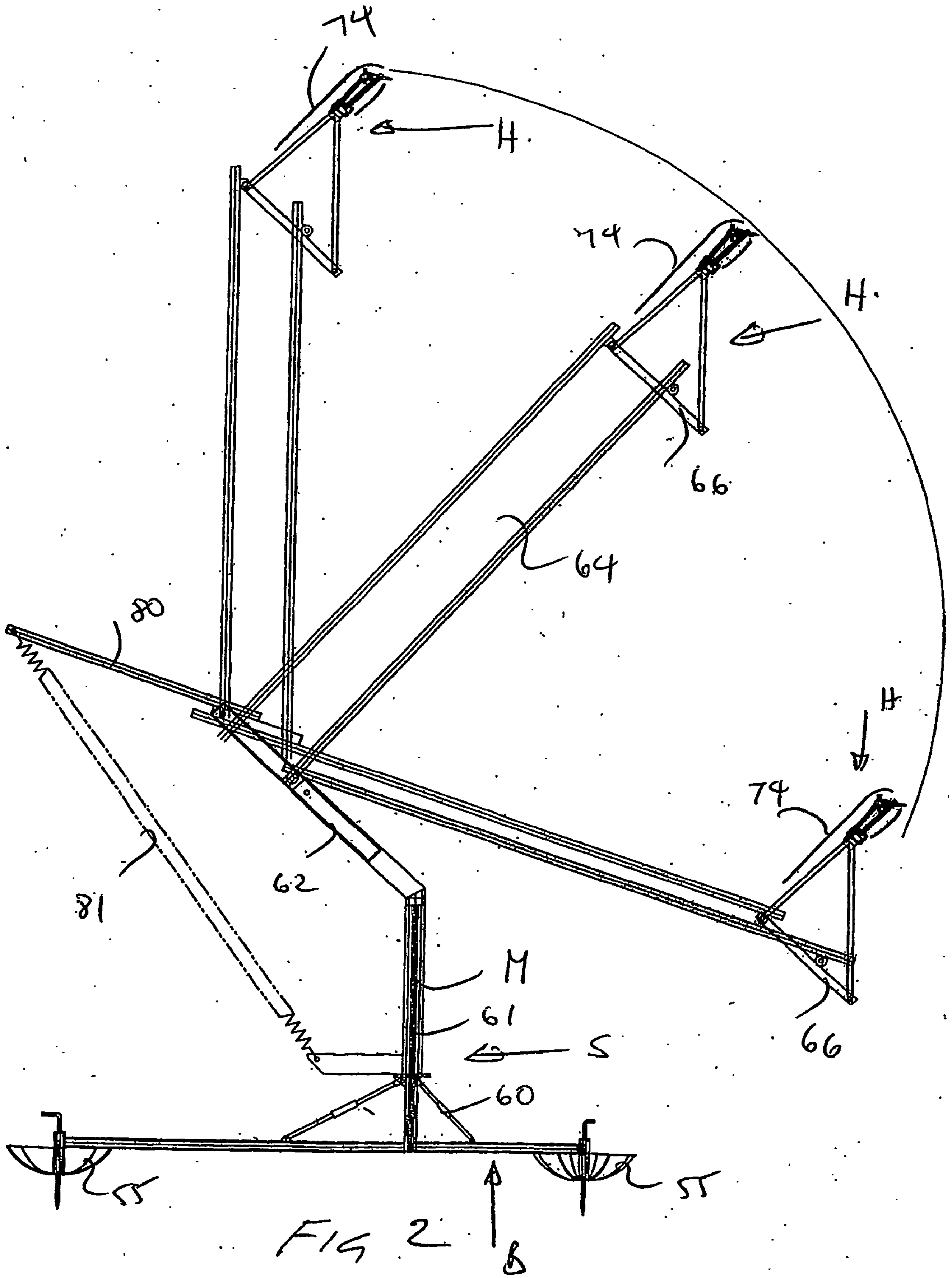

FIG 2

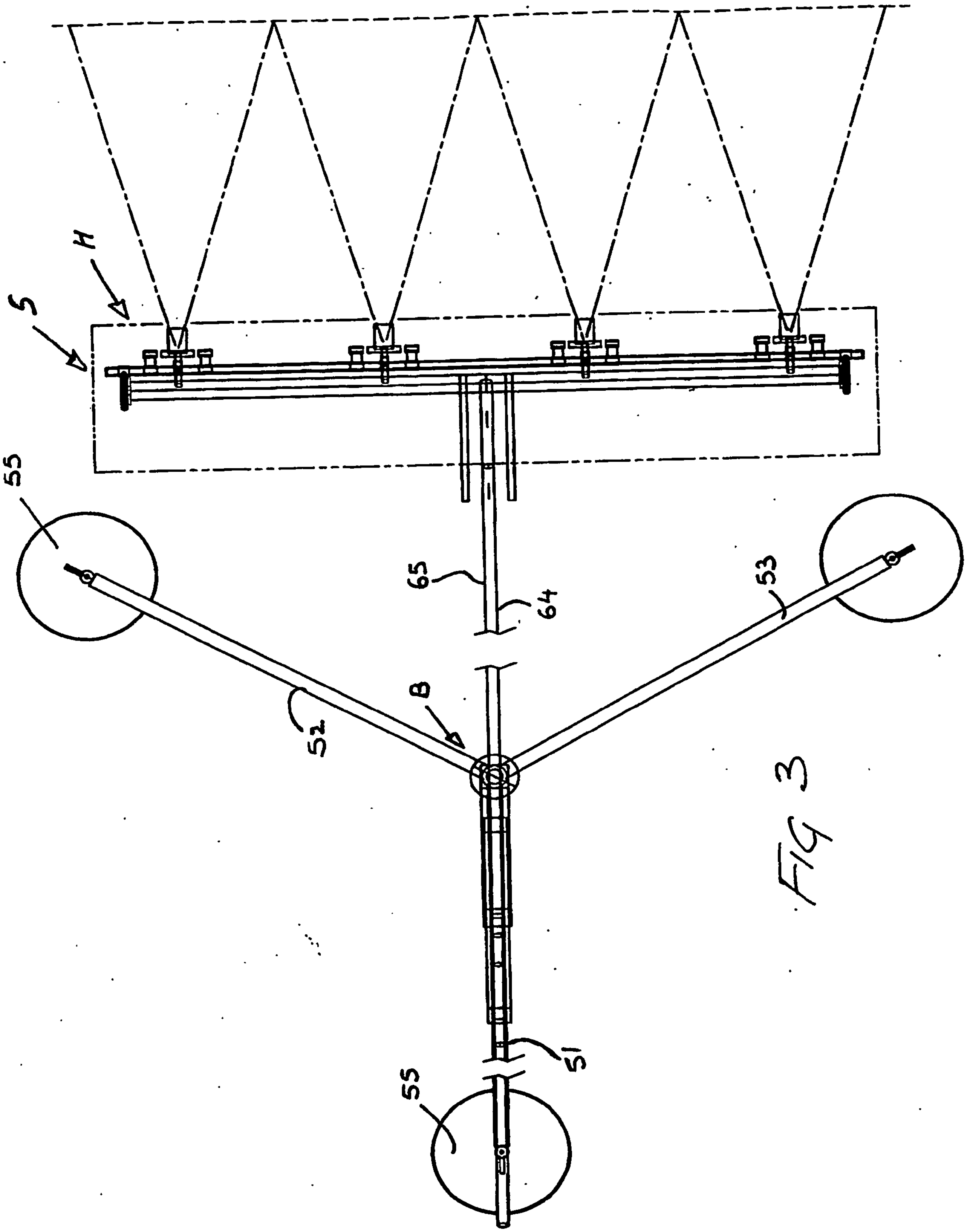

FIG 3

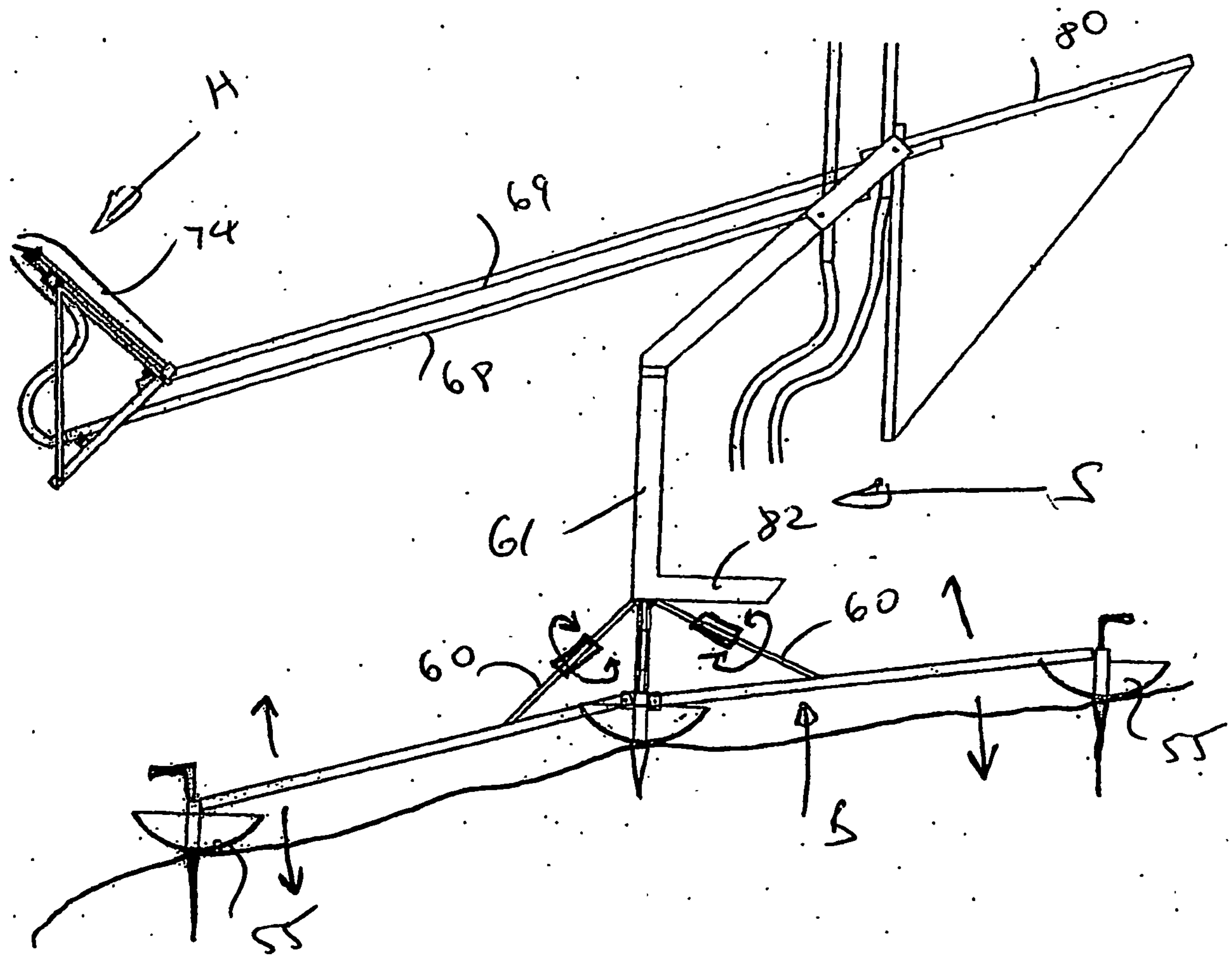

FIG 4

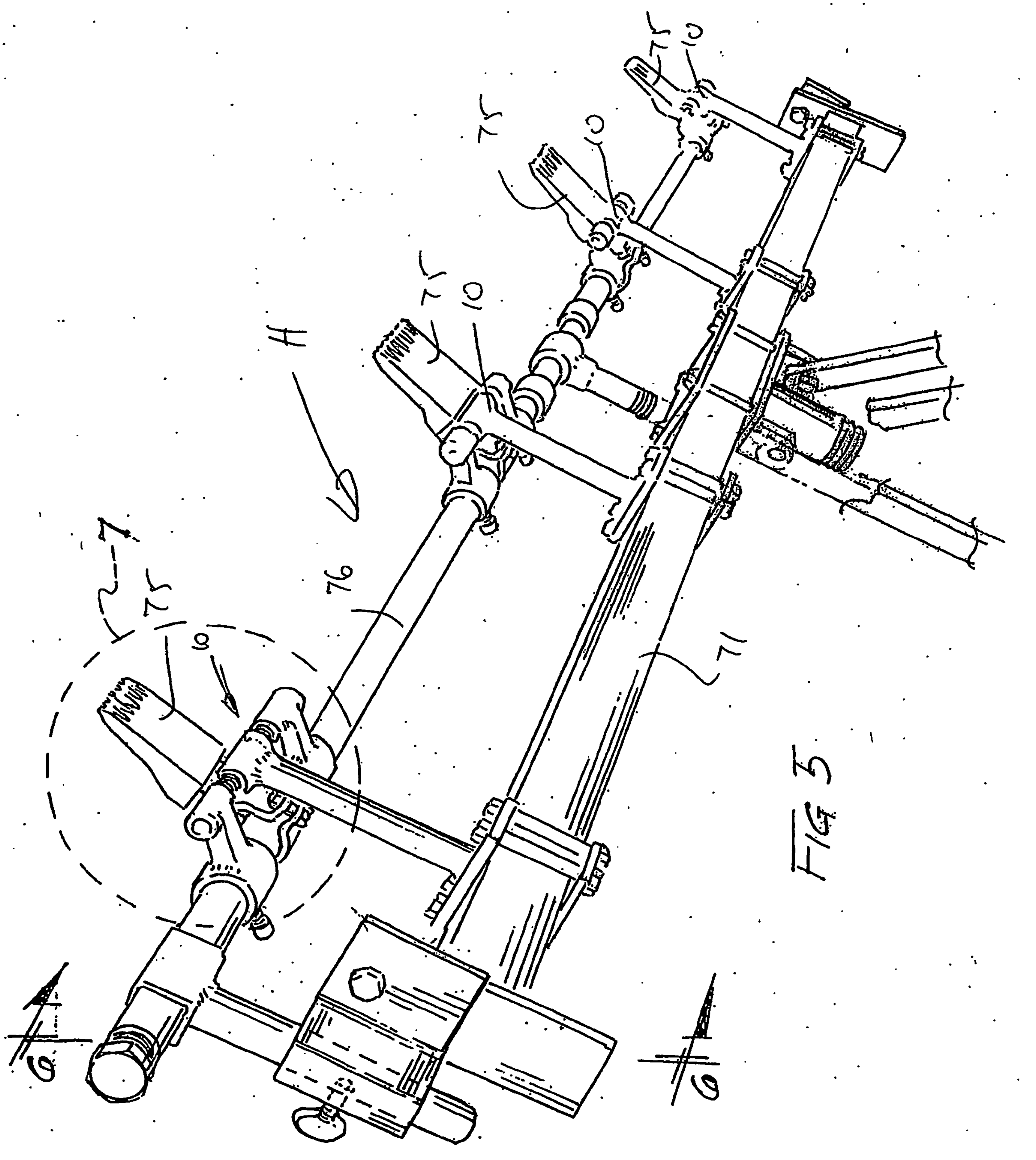

FIG 5

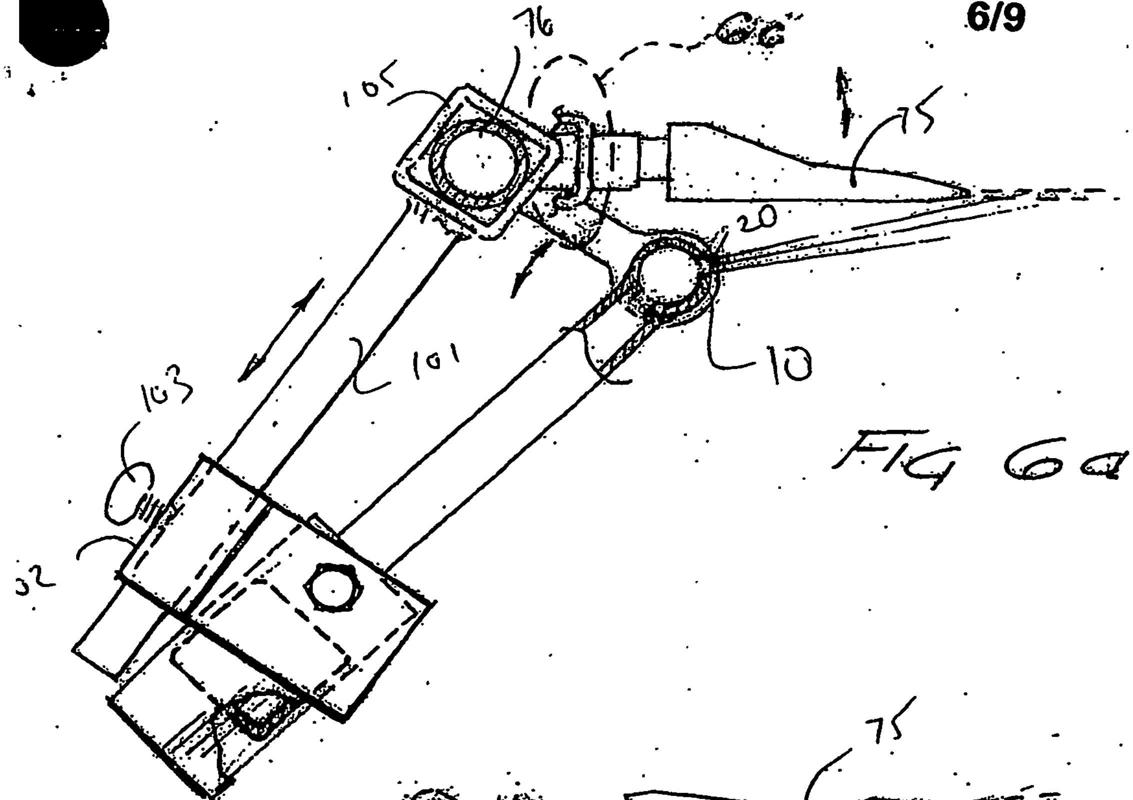

FIG 6a

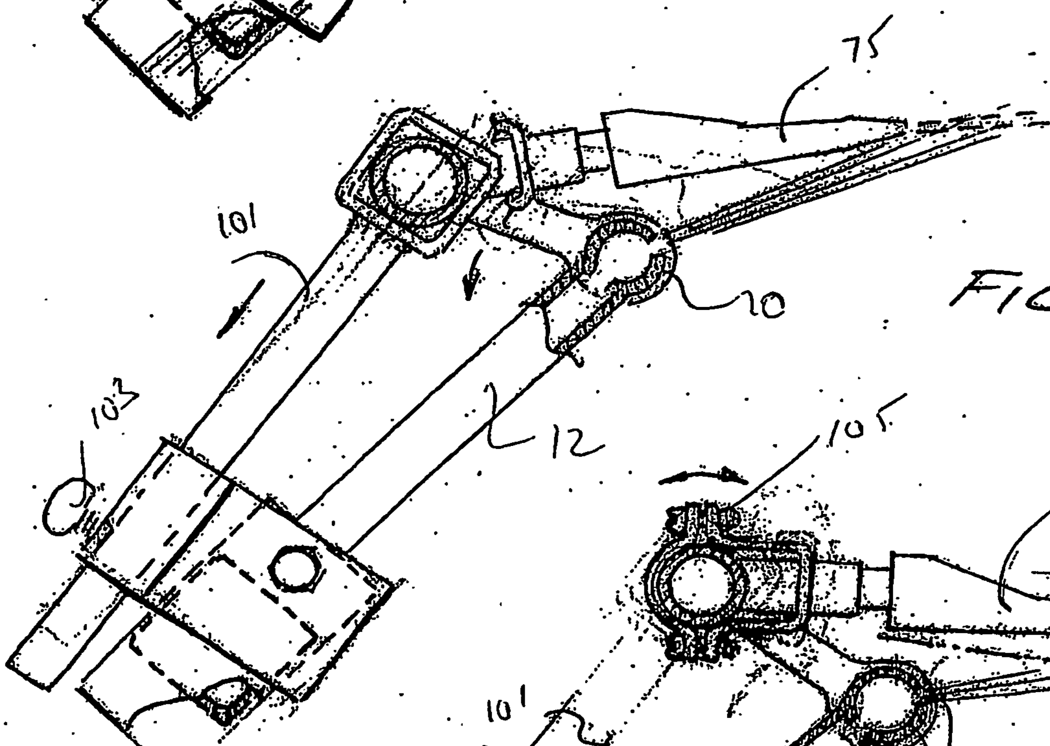

FIG 6b

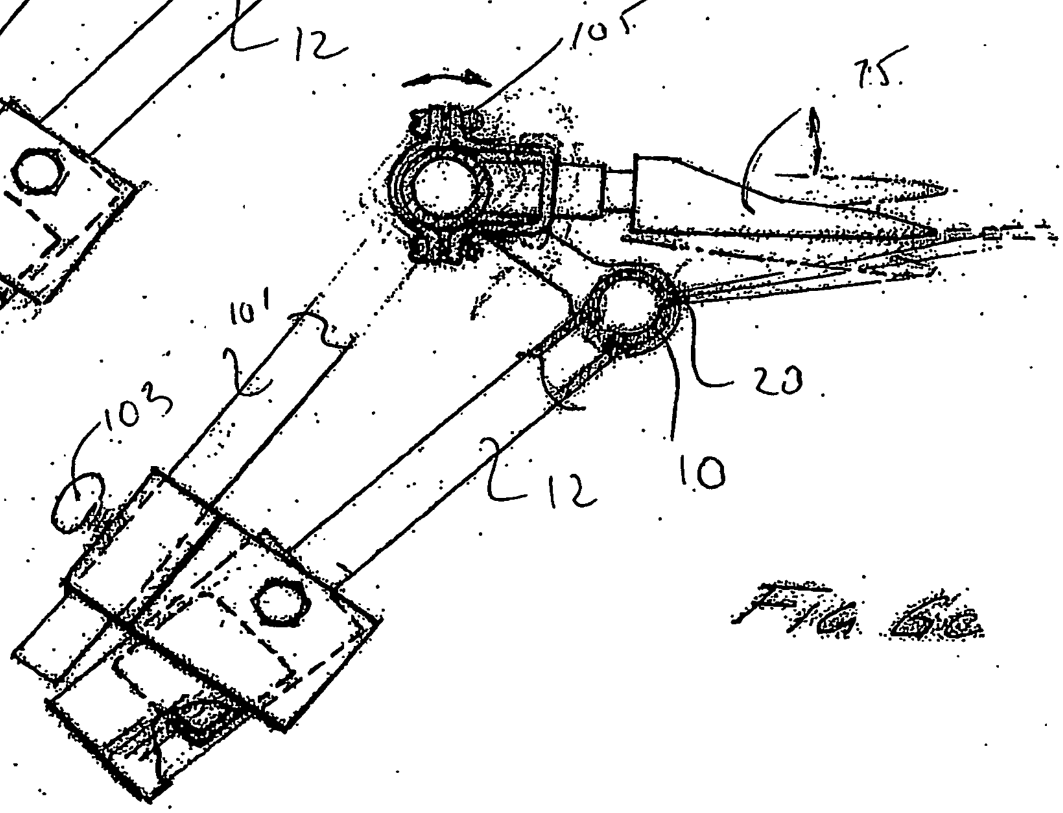

FIG 6c

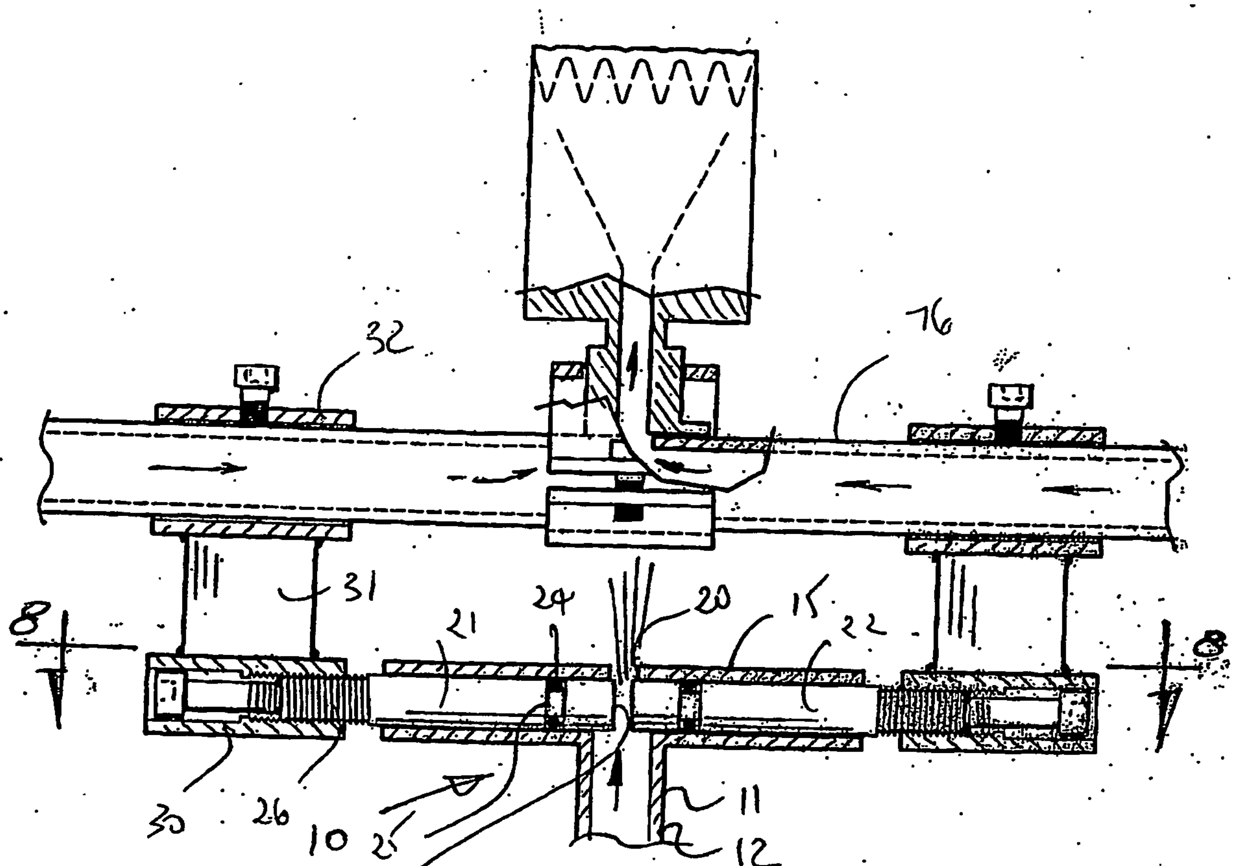

FIG 7

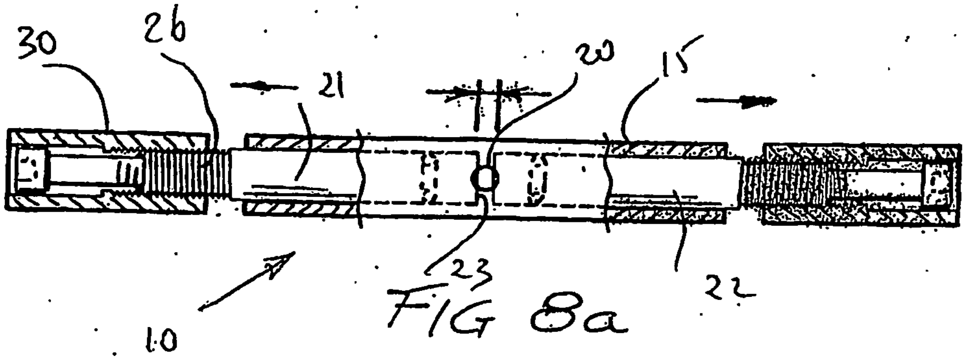

FIG 8a

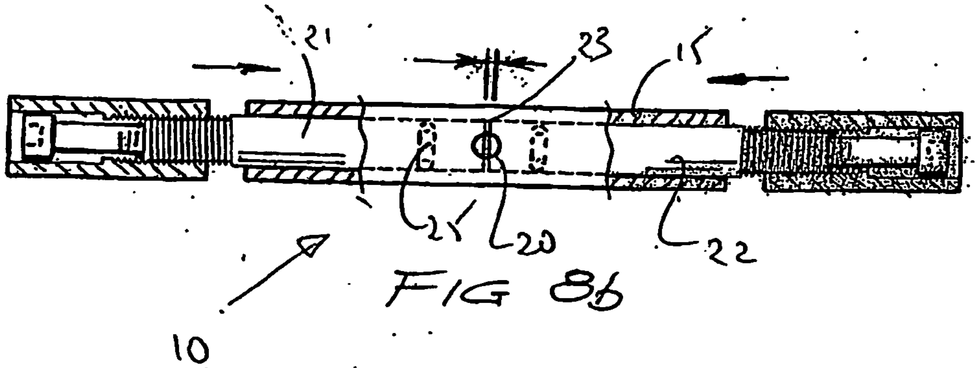

FIG 8b

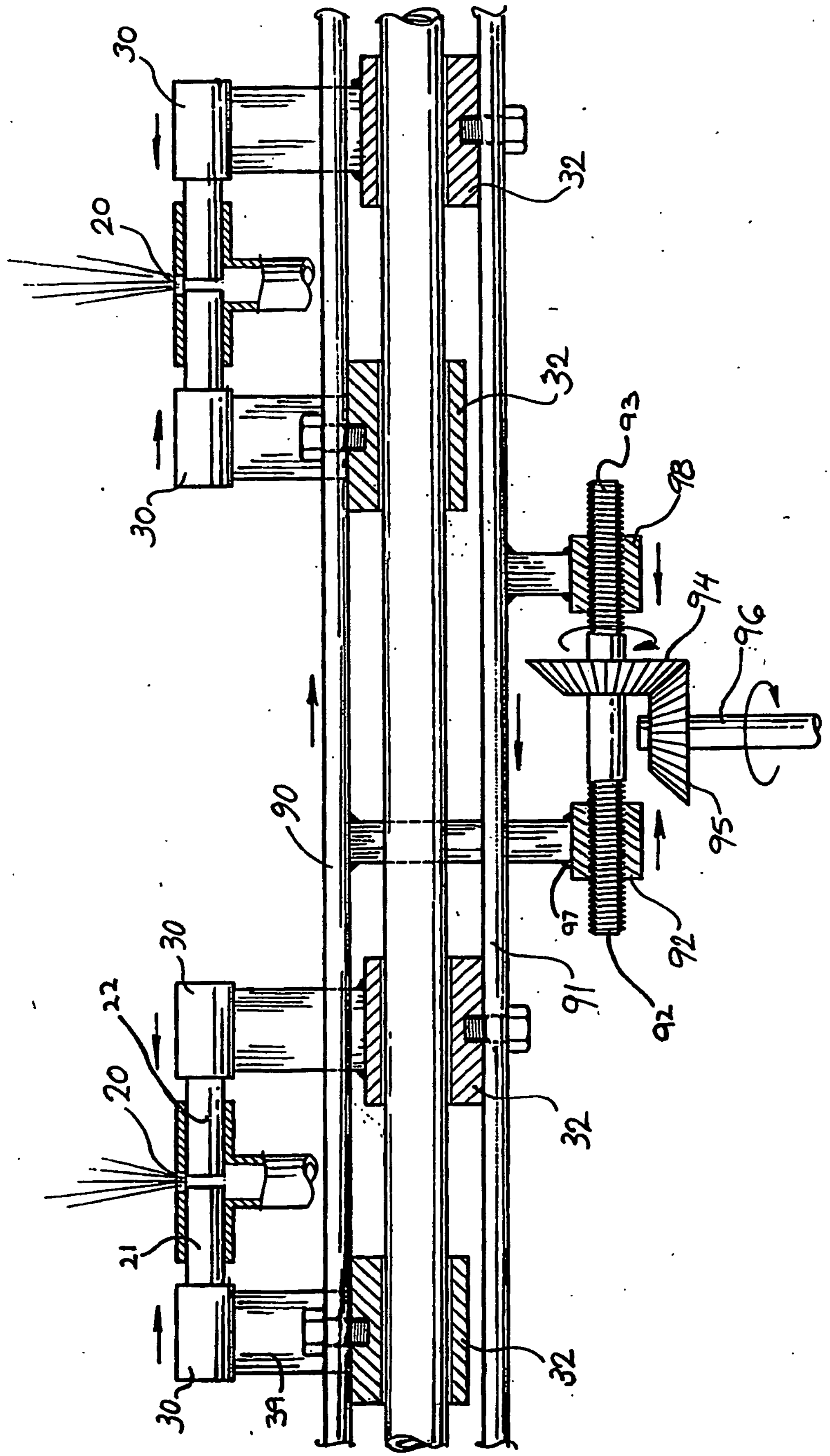

FIG 7A

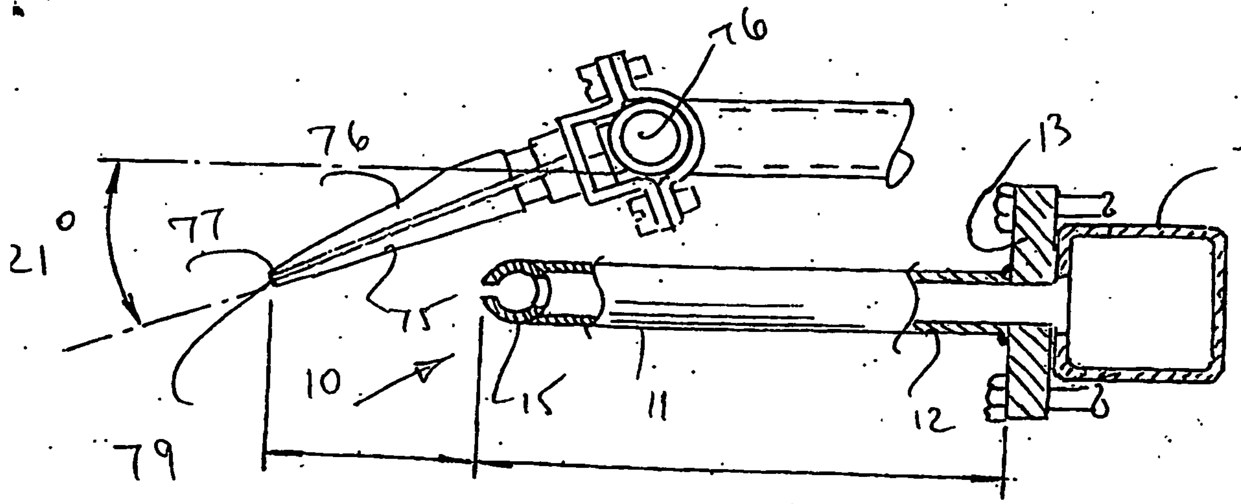

FIG 9

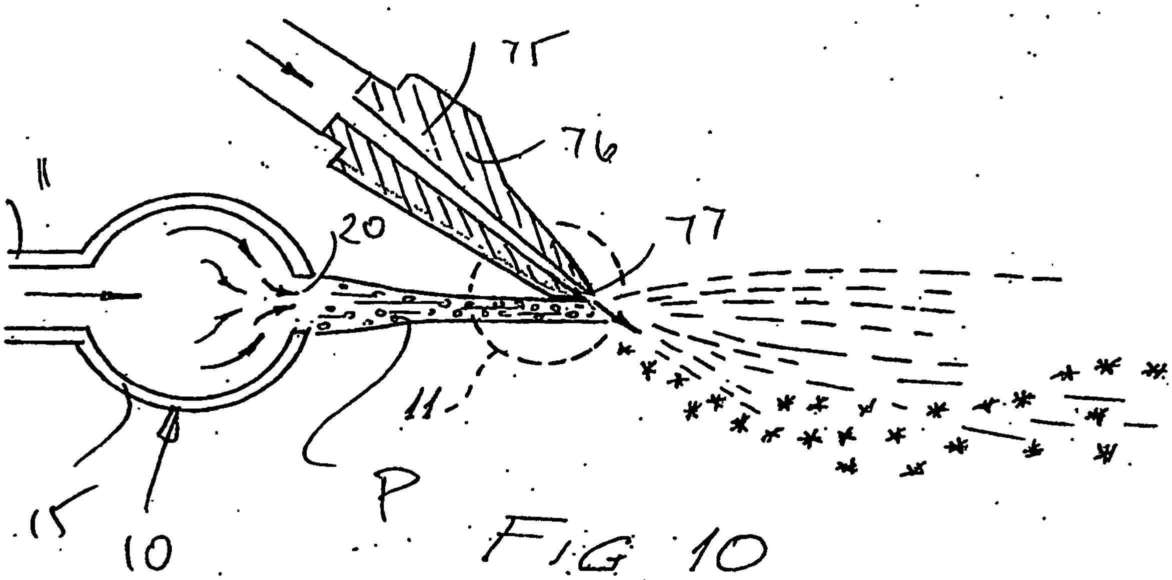

FIG 10

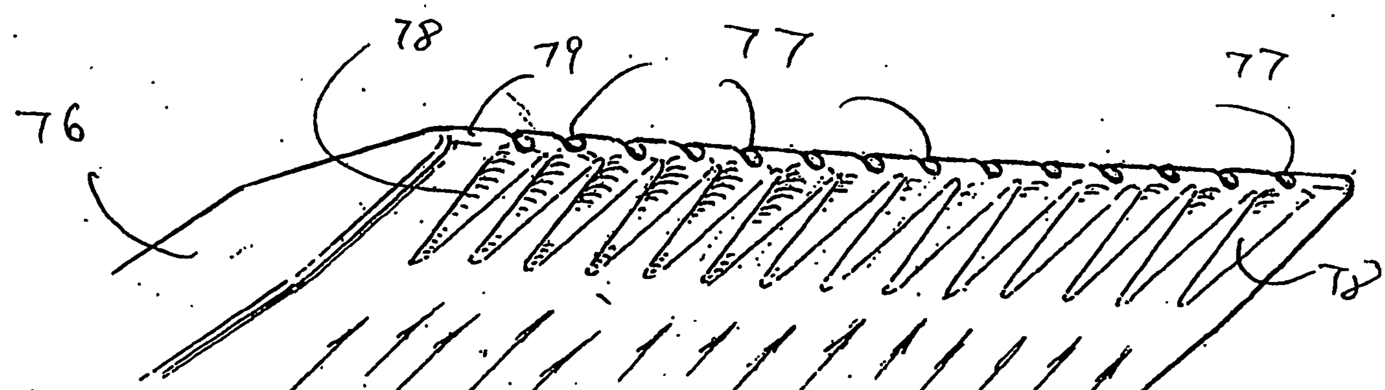

FIG 11